MICHIGAN STATE UNIVERSITY

Industrial/Organizational Psychology
and
Organizational Behavior

Situational Awareness in Teams with Distributed Expertise:

A Multi Level Approach

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Final Report

Air Force Office of Scientific Research

Grant Number:

F49620-95-1-0314

Period Funded:

1 April 1995 - 30 September 1998

REPORT DOCUMENTATION PAGE

AFRL-SR-BL-TR-99-

0044

1 AGENCY USE ONLY (*Leave Blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	November 30, 1998	Final April 1, 1995 - September 30, 1998

4 TITLE AND SUBTITLE

Situational Awareness in Teams with Distributed Expertise: A Multilevel Approach

5. FUNDING NUMBERS

F49620-95-1-0314

2313/BS

61102F

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8. PERFORMING ORGANIZATION REPORT NUMBER

98-1

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

~~AFISR/PKA~~ AFOSR/NL
110 Duncan Ave. Suite B115
Bolling AFB DC 20332-0001

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

Three or four person decision making teams with leaders and expertise distributed among staff members were studied as they performed on a command and control decision making simulation. Multiple experiments were conducted looking at team composition, means of communicating among team members, and other conditions in team settings, such as the form of feedback provided to the teams. Research on gender composition found all male teams, when compared to mixed gender teams and all female ones, spent more time discussing and developing the process by they would conduct the exercise than did teams with the other two compositions, . and, given the nature of the task and its time constraints, they performed less well. Research varying the mode of communication among team members found that teams, with a mix of multiple means of communication fit to the cognitive demands of the tasks, made more accurate decisions. Finally, decomposition of measures of decision making accuracy were able to pinpoint forms of accuracy predicted well and not well by the core components of the multilevel theory of team decision making.

14. SUBJECT TERMS

Team decision making; distributed decision making; distributed expertise; hierarchical teams

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
unclassified	unclassified	unclassified	

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Background

In early 1990, Ilgen and Hollenbeck began a project designed to study decision making in hierarchical teams with members who differed in expertise and status. A literature review was conducted (Ilgen, Major, Hollenbeck, & Sego, 1993), and a model of team decision making was developed based on an adaptation of a model frequently used to study individual's decision making behavior, the Brunswik Lens Model (Ilgen, Major, Hollenbeck, & Sego, 1995). This model was used to develop the Multilevel Theory of team decision making.

Concomitant with the theoretical work mentioned above, a team decision making simulation was constructed which allows for studying the behavior of four-person decision making teams. The simulation, known by its acronym, TIDE^2, for "team interactive decision exercise for teams incorporating distributed expertise" was used for most of the initial empirical work on the model. Extensive research with four-person teams established that the major behavioral constructs of interest in team decision making research can be successfully manipulated and studied using the TIDE^2 exercise (Hollenbeck, Sego, Ilgen, Major, Hedlund, & Phillips, 1997; Hollenbeck, Ilgen, & Tuttle, 1995). Data analytic methods for analyzing multi-level data were developed (Hollenbeck, Ilgen & Sego, 1994) and results employing this simulation generally supported the major tenets of the multi-level theory (Hedlund, Ilgen, & Hollenbeck, 1998; Hollenbeck, Ilgen, Sego, Hedlund, Major, & Phillips, 1995; Hollenbeck, Ilgen, LePine, Colquitt, & Hedlund, 1998).

The objectives of the present project were to link research conducted at Michigan State University on the Multilevel Theory with research being conducted at the Armstrong Laboratories at Brooks Air Force Base on team decision making and situational awareness. The first five months of this project (April 1995 to September 1995) were dedicated to establishing a common research agenda, sharing technology, and developing standardized tasks, protocols and measures for future studies. The principal investigators at Michigan State worked closely with personnel at the Armstrong Laboratory including Dr. Samuel Schiflett, Ms. Linda Barrett, Dr. Douglas Eddy (NTI Inc.), and Mr. Matt Dalrymple (SRL, Inc.) in generating a multi-lab collaborative program of research.

The result of this joint effort was an agreement to study four factors central to the Air Force's concerns about team decision making accuracy in command and control teams. These four factors included team coordination, team gender composition, the nature of communication media, and the potential disruptive influence of communication breakdowns. Of primary interest to the project was the potential main effect and interaction between these antecedents and team performance (e.g., how the type of communication media influences the relationship between gender composition and team performance or the effect of communication breakdowns on team performance).

In addition, this program of research was to use the Multilevel Theory of team decision making as a framework for understanding how and why the antecedents (team coordination, gender composition, media, and breakdowns) impacted decision making accuracy. According to the Multilevel Theory, the impact that these antecedents would have on overall team decision making accuracy is mediated by the three core

constructs of the theory. These are team informity (how much relevant information the team can bring to bear on the decision), staff validity (the predictive value of individual staff members' recommendations to the team leader) and hierarchical sensitivity (the degree to which the leader can accurately weigh the different opinions of staff members).

The remainder of the report presents discussions of work that was done within specific content areas addressed by this grant.

Sex Composition and Computer Mediated Communication

Literature review. The initial empirical work on the likely effects of sex composition on team decisions followed an extensive literature review (Hollenbeck, Ilgen, LePine, & Hedlund, 1995). The review was structured around an analysis of team decision making requirements from the perspective of the multi-level theory. Once sub-tasks associated with team decision making were identified, major conceptual and theoretical approaches to sex differences were reviewed and related to the critical sub-tasks in hierarchical decision making teams. It was argued that two different theoretical approaches, evolutionary theory and social role theory showed promise for improving understanding of the impact of sex composition on team performance.

Sex composition with TIDE^2 : Computer mediated communication only. Empirical investigation of sex composition effects were begun with a study conducted by the Armstrong Laboratories research team. In a study running in parallel with the Armstrong study, a preliminary examination into sex composition effects was performed at Michigan State University. An experiment was run with 49 teams of varied sex composition working on the AWACs version of TIDE^2 where there was no voice

communication between team members. For the most part, these 49 teams were replications of the 38 teams run at Armstrong Laboratories under similar conditions.

In the original Armstrong Laboratory study, focused on team decision making accuracy, there was only a single comparison that showed a statistically significant difference between teams that was attributable to sex composition. Specifically, it was found the all male teams outperformed teams where the leader was male but the staff was all female. Since there were six different configurations of teams in terms of sex composition, this allowed for 15 specific comparisons. At the .05 level of statistical significance, one would expect at least one significant comparison based solely upon chance. Hence, sampling error could not be ruled out as a possible alternative explanation for the single result discovered.

To reduce the possibility of sampling error as an alternative explanation, the results for the 49 teams run at Michigan State were combined with the 38 run at Brooks. Although sampling error was a potential problem in both these data sets when examined in isolation, the combined sample of 77 teams largely obviated sampling error issues. In the combined sample, no significant sex composition effects were found, and although only 1 out of 15 effects were significant in the MSU sample when used in isolation, this effect was not the same as that found in the Brooks study. Thus, we concluded that, on the traditional TIDE^2 synthetic task, there were not strong, consistent effects for sex composition.

Because there was no opportunity for voice communications in either of these studies, there were severe limits on both the frequency and content of communications between team members. Since communication differences are one of the more likely

avenues through which sex differences might manifest themselves, the traditional TIDE^2 task may not have been conducive to finding differences attributable to sex composition. Hence, we ran a second study that allowed voice communications.

Sex Composition and Voice Communications. Examined 68 teams of varied sex composition who worked on the AWACs version of TIDE^2. All teams communicated verbally over the Telex System, were recorded with the Racal System and these data were coded using categories of communication derived by tailoring general categories to the task.

Factor analytic results indicated that four factors accounted for the content of communications in decision making teams. These factors captured the degree to which the team's communications focused on (1) *inputs* (e.g., discussing the information regarding targets), *outputs* (e.g., discussing recommendations or the final decision), *process* (dealing with coordination issues), and *non-task issues* (e.g., social communications).

Regression results indicated that sex composition affected two aspects of the communication content, output (R^2 = .10) and process (R^2 = .29). Communication content, in turn, affected two core constructs of the Multilevel Theory, team informity (R = .70) and hierarchical sensitivity (R^2 = .20). Finally, the core constructs explained a large portion of the variance in team decision making accuracy (R^2 = .39), thus supporting the overall model that sex composition affected communication content which, in turn, affected the core constructs of the theory. Finally the core constructs affected team decision making accuracy. In each case, constructs intervening between

sex composition and team decision making accuracy mediated the composition effect, and core constructs mediated the effect of communication content on accuracy.

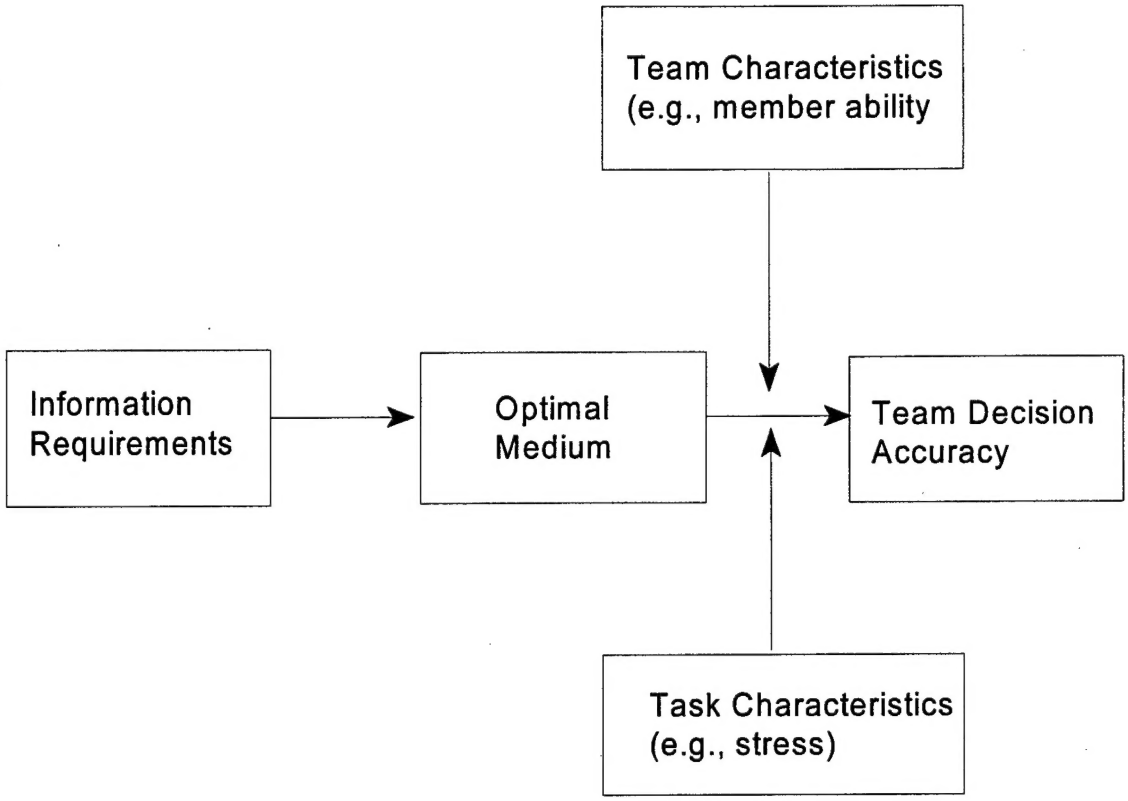
The nature of the effects suggested that all male teams performed worse relative to mixed team or all female teams, and that this was attributable to too much discussion of process as opposed to input and output. This in turn harmed their overall performance because it lowered team informity and hierarchical sensitivity. The results from this study are currently be written up for publication.

Communication Media

A study of the effects of communications media employed 103 teams that were randomly assigned to one of three communication media; (a) *all voice*, (b) *no voice* (computer mediated) or (c) *strategically mixed* communications. The strategic condition based medium selection on the memory requirements associated with the message (e.g., long term versus short term memory), requirements associated with speed of transmission (e.g., slow versus fast), and requirements for precision (e.g., precision required versus not required). Thus, in the strategically mixed condition, *electronic transmissions* were used for raw data regarding specific targets (high precision and speed, but no long term memory requirements), *voice communications* were used for feelings and subjective opinions regarding specific targets (low precision and low memory requirements, but high need for speed), and *written text messages* were used for task coordination messages that generalized across individual targets (high memory and precision requirements, but low speed requirements).

In the study we also examined the degree to which, the nature of the communication media interacted with characteristics of the team members (high versus

low ability) and the task (high stress versus low stress. Thus, testing the general model depicted as follows:



Results indicated that teams performing in the strategically mixed media condition outperform voice only and no voice teams (R^2 = .07), that high ability teams (operationalized in terms of staff validity) outperformed low ability teams (R^2 = .29), and that team member ability interacted with communication medium (R^2 = .09). The nature of this interaction indicated that the advantages of the strategically mixed communication medium were particularly pronounced in teams with low or varied ability. Results pertaining to stress, are still pending, and require a within team (i.e., target by

target analysis) that is preceding now. The results from this study is being written up for publication at this time.

Communication Breakdowns

This study used the Multilevel Theory to analyze the implications of communication breakdowns in the area of team decision making. It employed 143 teams that worked on the TIDE^2 task and experienced communication failures during the course of a two hour experimental session. The primary outcome studied was the degree to which communication failures lead to inaccurate decision making, and the mechanisms (in terms of the core constructs of the Multilevel Theory) through which this took place. This study also examined the degree to which characteristics of the team members such as cognitive ability (LePine, Hollenbeck, & Ilgen, 1997), characteristics of the task (goals and feedback), and characteristics of the communication failure (gradual versus abrupt) moderated the negative impact of communication failures.

There were several noteworthy results from this study. First, teams characterized as having higher levels of cognitive resources had higher odds of successfully working around (i.e., adapting to) the communication breakdown. Second, there was also a relationship between the nature of the breakdown and adaptation. Teams were more likely to detect and successfully overcome an abrupt breakdown relative to a gradual one. Finally, the nature of the team's performance relative to the team's goals was also a significant factor affecting the response to the breakdown. Specifically, teams who were performing below their goal levels were less likely to successfully adjust to the communication breakdown relative to teams that were performing above their goal levels. Performing above their goal levels provided teams with some degree of

psychological "slack" that could be used for trial and error experimentation in working around the breakdown. Teams that were performing below their goal levels tended to restrict their focus and were unable to adapt well to the communication failure (LePine, Hollenbeck, & Ilgen, 1998).

Accuracy Decomposition

One important external development that occurred while we were working on this grant was the publication of Gigone and Hastie's (1997) article on accuracy decomposition. In this article, Gigone and Hastie showed how conventional measures of decision accuracy could be decomposed into three distinct components: *linear consistency*, *mean bias* and *variability bias.* Gigone and Hastie argued that, given the relative independence of these three facets, researchers should be developing theories for each of the different forms of accuracy rather than or in addition to theories of overall accuracy criterion since the components may not all have similar causes.

We conceptually analyzed the Multilevel Theory against the three facets of accuracy isolated by Gigone and Hastie (1997), and there seemed to be a number of reasons to believe that this theory is primarily a theory of linear consistency, rather than mean bias or variability bias. We then empirically tested the generalizability of the Multilevel Theory across these three different facets of accuracy with an existing data set that included 105 teams who worked on the TIDE^2 task. These data are reported in Hollenbeck, Colquitt, Ilgen, LePine, and Hedlund (1998).

The results of this study indicated that the core constructs of the Multilevel Theory accounted for 63% of the variance in linear consistency, 20% of the variance in variability bias, but none of the variance in mean bias. We concluded that the Multilevel

Theory is primarily a theory of linear consistency, and that alternative theories needed to be developed to deal with other facets of accuracy, especially mean bias.

Mean Bias Study

Criterion decomposition is a technique that attempts to improve a theory's ability to predict a criterion by adding variables that are specifically aimed at sub-components of the criterion least well predicted by the theory. The purpose of the mean bias study was to use this approach in attempting to extend the Multilevel Theory (MLT) of team decision making. Specifically, this study examined one individual difference variable (team member aggressiveness) and one situational factor (direct feedback on levels of mean bias) that might be expected to affect mean bias, and tested the degree to which these factors improve the MLT's ability to predict overall decision making accuracy. As such, this was the first study in the area of decision making accuracy that employed mean bias as the primary dependent variable, and thus, provides the first evidence regarding factors that might predict this component of overall team decision making accuracy.

Consistent with past research (Hollenbeck, Colquitt et al., 1998), results from this study of 320 individuals in 80 four-person teams confirmed that the MLT predicts overall decision accuracy primarily because it is a theory of linear consistency. The core constructs of the MLT explained almost no variance in mean bias. The best way to improve this theory, therefore, is to add variables to it that would be predictive of mean bias--a component of overall accuracy that is independent of linear consistency. This general proposition was supported in that staff member aggressiveness and feedback both had direct effects on mean bias. These two variables also interacted in the sense

that feedback on mean bias neutralized the effect of staff aggressiveness. Consistent with expectations, when staff aggressiveness and mean bias feedback were added to the core constructs of the MLT, this enhanced the amount of variance explained in overall team decision making accuracy by on mean bias improved the prediction of overall team decision accuracy over and above that predicted by the core constructs of the MLT alone by 9%. This study has been written up and was recently submitted for publication (LePine, Hollenbeck, Ilgen, Colquitt, & Ellis, 1998).

Summary and Conclusion

Small decision making teams with leaders and staff members whose areas of expertise overlap but also differ in several respects continued to be the focus of this research effort. As has been the case with our work in the past, critical issues related to the quality of decisions made by such teams are identified both from an understanding of the types of problems faced by teams in the field and by theoretical issues raised by us and other researchers studying teams. These issues are then addressed in the laboratory setting using three or four person teams trained on a decision making simulation. They perform in that setting for two to three hours.

The present research effort began by addressing conditions likely to influence the quality of decisions in teams of the type described above. The conditions of interest were team composition and communication mode. Composition focused on gender for two reasons. First, at a time when integration of the sexes across most all job classifications is both a social and a legal imperative, decision making teams are and must continue to be composed of both males and females. Yet, past research has found that the composition of teams can affect team processes and outcomes.

Research on this grant using decision making teams found both process and outcome effects. The data indicated that all male teams were more likely than mixed or all female teams to spend greater amounts of time and effort discussing the process by which they should function as a team than were mixed gender or all female teams, and that greater amounts of time negatively impacted on team decision making accuracy. The research points to the need to consider gender composition from a more complex standpoint than simply asking if it affects performance. Rather, there is a need to understand the task from the standpoint of a clear task analysis and then ask what team processes in the particular task setting are and are not likely to be affected by gender composition and is the composition likely to affect performance?

Other conditions investigated with respect to team decision making also began with the assumption that the task demands serve as a basis for looking at the effects of the conditions on team decision making. This work focused on extending previous research to include typical means of communication open to small decision making teams. In particular, we employed both communications sent through computer terminals as well as voice communications. In some cases, teams were restricted to one or the other form of communication. In other cases, we first analyzed the task from the standpoint of the demands that the form of information needed to do the task made on communications. For example, when the information needed to be precise and stored in some way that was easily retrievable without a bias being introduced between the time that the message was originally received and the time when it was needed, information was sent and stored electronically. On the other hand, when the information was somewhat ambiguous and needed to be refined and/or agreement was needed

among team members to be able to deal with the information, communicating by voice seemed, a priori, to be a preferred mode of communication. The data confirmed that a mixed mode communication system where the mode was dictated by the information demands of the task led to better decisions than either mode in its pure form. It is suggested that future research needs to explore ways to refine the ways in which team decision making tasks are analyzed as to their communication demands, then the communication mode can be selected more strategically to obtain a better fit to the communication demands of the subtasks faced by the teams.

Finally refinement of the initial model of team decision accuracy (see Hollenbeck, Ilgen, Sego et al., 1995) was the focus of two studies. First, following the publication of Gigone and Hastie's (1997) Psychological Bulletin article on decomposing constructs like our team decision accuracy measure, team decision data were analyzed decomposing our accuracy measure into the three components. These data showed that when teams were inaccurate in our setting, the three components of our model, team informity, staff validity, and hierarchical sensitivity, were able to predict variability bias quite well. Mean bias was poorly predicted. A second study focused in on mean bias by seeing whether feedback given to team members and an individual difference critical for the type of simulation being used for the decision making task would improve our ability to predict mean bias. The results showed that adding additional predictors and their interactions did improve prediction of mean bias in the teams. Thus, the work offered information useful for refining the prediction of team decision accuracy and its components. As with all the studies undertaken in this research effort, attention was directed toward improving understanding of factors that influence the ability of teams to

make accurate decisions when those teams have a leader responsible for their decision and staff members who have expertise that overlaps but is not totally redundant. In all cases, the multi-level theory was found to be a useful guide for the research.

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Products to Date(11/30/98) on Grant F49620-95-1-0314

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